# Secondary electron contrast in doped semiconductor with presence of a surface ad-layer

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Keywords: dopant contrast, secondary electrons, semiconductor

The scanning electron microscopy (SEM) has proven itself efficient for determining dopant concentrations in semiconductors. Image contrast between differently doped areas is observable in the secondary electron emission [1]. Multiple studies have revealed quantitative relations between the image contrast and dopant concentration [2,3,4]. However, further examination shows the dopant contrast level of low reproducibility and dependent on additional factors like the primary electron dose [5], varying energy and angular distributions of the SE emission [3, 6] and also presence of an ad-layer on the semiconductor surface [7].

Under high-vacuum conditions this ad-layer can consist of the carbon contamination, created by decomposition of hydrocarbons under primary beam impact, and of the oxide layer. In order to understand the origin of the dopant contrast we have to examine it in dependence on the status of the sample surface.

First experiments have been performed on p-type doped patterns ($1\times10^{19}$ cm$^{-3}$ of boron atoms) made on a Si (111) n-type substrate ($1\times10^{15}$ cm$^{-3}$ of phosphorus atoms). The p-type doped areas were covered by a thin native oxide layer while the substrate was covered by almost 1 μm thick oxide layer. The sample in the as-inserted status was observed in the Jeol 6700F microscope with a CFE gun and the standard Everhart-Thornley (LEI) and in-lens (SEI) detectors.

The aim of first experiments was to observe the sample under various impact energies of primary electrons (0.5 keV to 10 keV). The contrast between p- and n-type areas has been found reverting at 3 keV impact energy (Fig. 1) and dependent on the working distance. However, the same behavior was not met with the sample covered by a native oxide layer only (Fig. 2), contrary to what was reported in [8].

In Fig. 3 we see the difference between the secondary electron emission at 1 keV from a part of the substrate (covered with 1 μm oxide layer) scanned for the first time and after several scans made. The substrate signal obviously decreases with increasing total electron dose.

The observed phenomenon has not been sufficiently explained as yet. For this reason the experiments will continue on doped silicon samples covered with intentionally prepared oxide films of various thicknesses.

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G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology,
DOI: 10.3217/978-3-85125-062-6-098, © Verlag der TU Graz 2009

9. The study was supported by the GACR project no. GP102/09/P543 and by the GAASCR project no. IAA100650803.

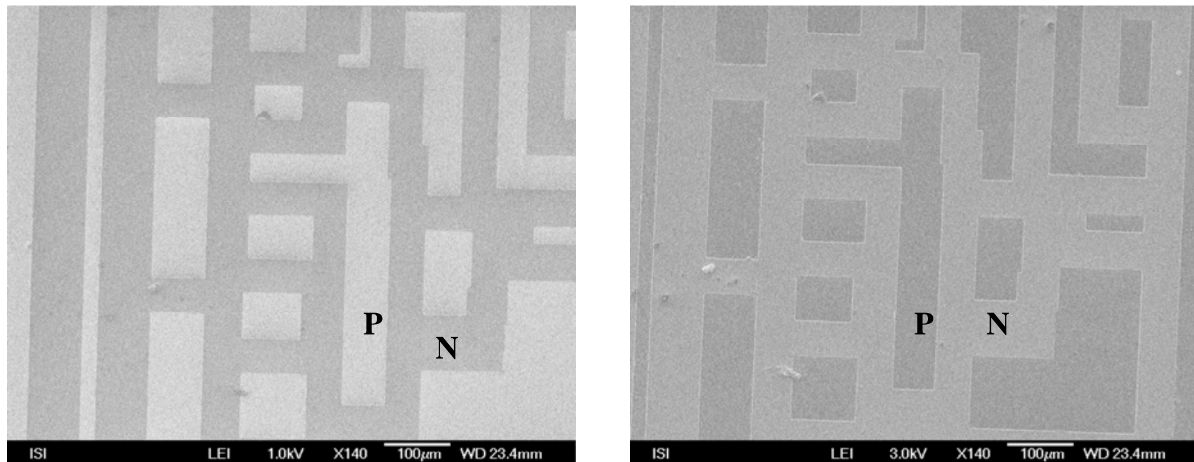


**Figure 1.** P-type doped patterns ($1\times10^{19}$ $cm^{-3}$), covered by the native oxide, on a n-type Si substrate ($1\times10^{15}$ $cm^{-3}$) covered by a 1 μm oxide, imaged with the LEI detector at 1 keV (left) and 3 keV (right).

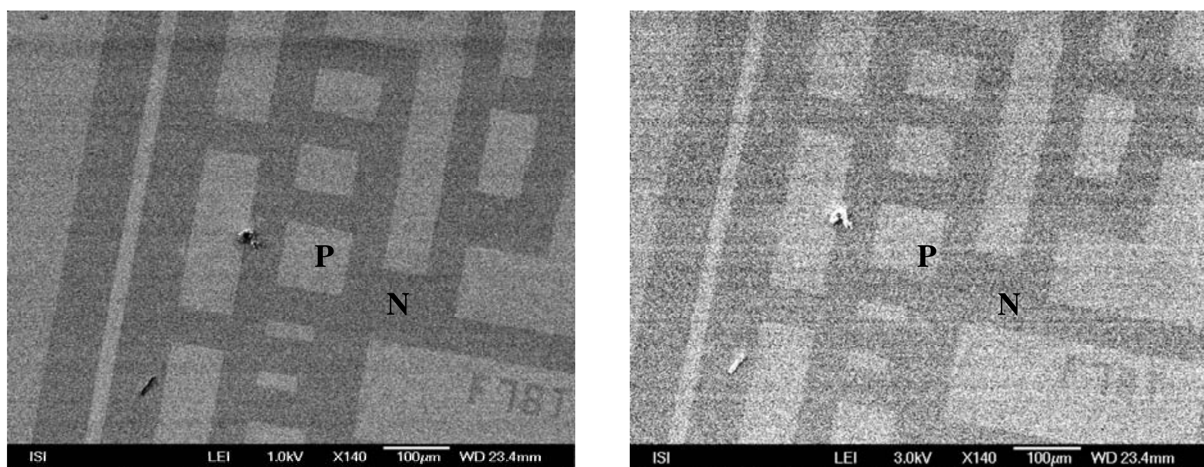


**Figure 2.** P-type doped patterns ($1\times10^{19}$ $cm^{-3}$) on the n-type Si substrate ($1\times10^{15}$ $cm^{-3}$), all covered by the native oxide layer and imaged with the LEI detector at 1 keV (left) and 3 keV (right).

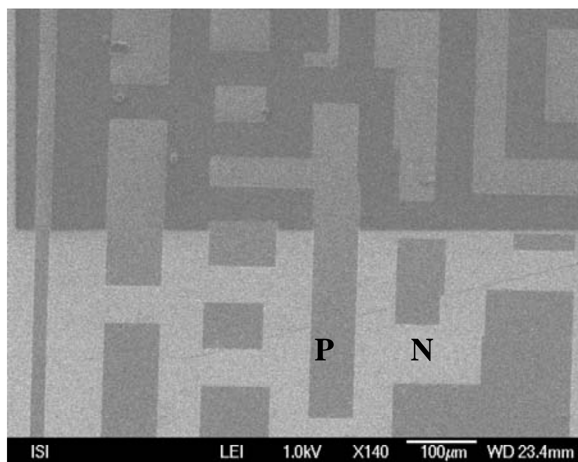


**Figure 3.** P-type doped patterns ($1\times10^{19}$ $cm^{-3}$), covered by the native oxide, on a n-type Si substrate ($1\times10^{15}$ $cm^{-3}$) covered by a 1 μm oxide, imaged with the LEI detector at 1 keV; area scanned for the first time (lower part) and a part scanned several times (upper part).


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